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BATTERY SAFETY MONITOR SYSTEM

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BACKGROUND OF THE INVENTION

3 The present invention is generally in the field of battery monitors. Battery monitors
4 provide data for at least one battery, which comprises cells or strings of cells.

5 Typical battery monitors do not incorporate safety devices. In addition, typical battery
6 monitors have relatively high power consumption.

7 Therefore, a need exists for battery monitors that incorporate safety devices and reduce
8 power consumption.

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2 BRIEF DESCRIPTION OF THE DRAWINGS

3 FIGURE 1 is a block diagram of one embodiment of the present invention.

4 FIGURE 2 is a block diagram of one embodiment of the present invention.

5 FIGURE 3 is a block diagram of one embodiment of the present invention.

6 FIGURE 4 is a flowchart of an exemplary application of the present invention.

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1 DETAILED DESCRIPTION OF THE INVENTION

2 The present invention is directed to a method and apparatus for battery safety monitor
3 systems. Although the invention is described with respect to specific embodiments, the
4 principles of the invention, as defined by the claims appended herein, can obviously be applied
5 beyond the specifically described embodiments of the invention described herein. Moreover, in
6 the description of the present invention, certain details have been left out in order to not obscure
7 the inventive aspects of the invention. The details left out are within the knowledge of a person
8 of ordinary skill in the art.

9 The drawings in the present application and their accompanying detailed description are
10 directed to merely exemplary embodiments of the invention. To maintain brevity, other
11 embodiments of the invention that use the principles of the present invention are not specifically
12 described in the present application and are not specifically illustrated by the present drawings.
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14 DEFINITIONS

15 The following definitions and acronyms are used herein:

16

17 Acronyms:

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19 BSMS – Battery Safety Monitor System

20 DCDD – Data Collection and Display Device

21 MUX – Multiplexer

22 A/D – Analog-to-Digital

23 PTC – Positive Thermal Coefficient

24 UART – Universal Asynchronous Receiver Transmitter

25

26 Definitions:

27

28 Cell – one unit of a battery having a cathode and an anode

29 Battery Cell String – multiple cells in series

30 Battery array or Battery – a configuration of cells in either parallel or serial or combination.

1 The present inventive battery safety monitor system includes a battery monitor and a data
2 collection and display device. In one embodiment, the present invention incorporates safety
3 devices. In one embodiment, the present invention reduces power consumption. In one
4 embodiment, the present invention can measure voltages of individual battery cell strings for a
5 plurality of battery cell strings. The present invention is particularly useful in monitoring
6 lithium-based batteries (e.g., lithium/thionyl chloride batteries).

7 FIGURE 1 is a block diagram of one embodiment of the present invention. As shown in
8 FIG. 1, battery safety monitor system (BSMS) 100 includes at least one battery monitor 110 and
9 data collection and display device (DCDD) 120. Battery monitor 110 is operatively coupled to
10 DCDD 120. In one embodiment, BSMS 100 includes a plurality of battery monitors 110. In one
11 embodiment, BSMS 100 includes a lone battery monitor 110. As described in detail below with
12 reference to FIG. 2, battery monitor 110 includes at least one battery. Battery monitor 110
13 obtains information regarding at least one battery and outputs data to DCDD 120.

14 DCDD 120 includes digital multiplexer (MUX) 130, microcontroller 140, at least one
15 display device 150 and power supply 160. Digital MUX 130 is operatively coupled to and
16 receives data (e.g, digital voltage signals) from at least one battery monitor 110. Digital MUX
17 130 is operatively coupled to and receives power from power supply 160. Digital MUX 130 can
18 receive power from microcontroller 140. Digital MUX 130 is capable of selectively receiving
19 input data from one of a plurality of battery monitors 110. Digital MUX 130 is operatively
20 coupled to and receives control signals from microcontroller 140. These control signals can
21 include information regarding input selection. Digital MUX 130 outputs data to microcontroller
22 140. Microcontroller 140 is operatively coupled to and receives power from power supply 160.
23 Digital MUX 130 outputs power to battery monitor 110. Microcontroller 140 is operatively
24 coupled to and receives data from digital MUX 130. Microcontroller 140 includes software,
25 firmware or instruction set, which operates microcontroller 140. Microcontroller 140 is capable
26 of controlling at least one display device 150. In one embodiment, microcontroller 140 controls
27 a plurality of display devices 150.

28 Display device 150 receives commands and/or data from microcontroller 140 regarding
29 battery conditions. Display device 150 can include, for example, visual alarms, audible alarms,
30 relay switches and serial interfaces coupled to display computers. In one embodiment, display
31 device 150 is a set of lights (e.g., light emitting diodes) capable of indicating battery conditions.

1 In one embodiment, display device 150 is an audio speaker (e.g., beeper) capable of sounding to
2 indicate danger. In one embodiment, display device 150 is a relay switch coupled to an external
3 alarm, where the relay switch closes to indicate danger. In one embodiment, display device 150
4 is a UART to RS232 converter coupled to a display computer. Display device 150 is operatively
5 coupled to and receives power from power supply 160. In one embodiment, DCDD 120 includes
6 a plurality of display devices 150. Power supply 160 is separate from battery cells being
7 monitored, and thus, reduces battery power consumption.

8 FIGURE 2 is a block diagram of one embodiment of the present invention. FIG. 2 is a
9 block diagram of one embodiment of battery monitor 110 of FIG. 1. As shown in FIG. 2, battery
10 monitor 210 includes at least one string unit 212, analog multiplexer (MUX) 230, zener diode
11 240, analog-to-digital (A/D) converter 250, wetness detector 254, microcontroller 260, serial
12 interface 270, optoisolator 280 and connector 290. As described in detail below with reference
13 to FIG. 3, battery monitor 210 includes a battery cell string and at least one safety device. String
14 unit 212 reduces danger via at least one safety device and outputs voltage signals to analog MUX
15 230. In one embodiment, battery monitor 210 includes a plurality of string units 212. In one
16 embodiment, battery monitor 210 includes a lone string unit 212. Analog MUX 230 is
17 operatively coupled to and receives voltage signals from at least one string unit 212. In one
18 embodiment, analog MUX 230 is operatively coupled to a plurality of string units 212. Analog
19 MUX 230 is capable of selectively receiving voltage signals from one of a plurality of string
20 units 212 and outputting the voltage signals. In one embodiment, analog MUX 230 is capable of
21 selectively isolating reception of voltage signals from a plurality of string units 212, which
22 reduces power consumption of battery monitor 210. Analog MUX 230 is operatively coupled to
23 and receives control signals from microcontroller 260, which can contain input selection
24 information.

25 As shown in FIG. 2, Zener diode 240 is operatively coupled to and receives voltage
26 signals from analog MUX 230. Zener diode 240 reduces the voltage signals to low voltage
27 signals. Zener diode 240 outputs low voltage signals. A/D converter 250 is operatively coupled
28 to and receives low voltage signals from zener diode 240. A/D converter 250 converts the low
29 voltage signals into digital signals, which represent voltage measurements of one string unit 212
30 of a plurality of string units 212. A/D converter 250 is operatively coupled to microcontroller
31 260 and wetness detector 254. Wetness detector 254 is capable of detecting dangerous battery

1 conditions such as, for example, battery venting of thionyl chloride. In one embodiment,
2 wetness detector 254 includes two narrowly spaced conductors, which are operatively coupled to
3 a high impedance voltage and an input to A/D converter 250. In one embodiment, wetness
4 detector 254 operates by producing a reduced voltage when condensation of liquids such as
5 thionyl chloride creates a low-impedance path between two narrowly spaced conductors. A/D
6 converter 250 receives voltage signals from wetness detector 254 and outputs digital signals.

7 Microcontroller 260 receives digital signals from A/D converter 250. Microcontroller
8 260 is a low power microcontroller. Microcontroller 260 includes software, firmware or
9 instruction set, which operates microcontroller 260. Microcontroller 260 outputs control signals
10 to A/D converter 250 and analog MUX 230. A/D converter 250 receives control signals from
11 microcontroller 260, which start a conversion process. Microcontroller 260 outputs digital
12 signals. Serial interface 270 is operatively coupled and receives digital signals from
13 microcontroller 260. In one embodiment, serial interface 270 comprises a universal
14 asynchronous receiver transmitter (UART). In one embodiment, battery monitor 210 includes a
15 Microchip PIC16LF877, which includes A/D converter 250, microcontroller 260 and serial
16 interface 270. Serial interface 270 outputs digital signals. Optoisolator 280 is operatively
17 coupled to and receives digital signals from microcontroller 260. Optoisolator 280 reduces
18 danger by preventing reverse currents, which can be introduced by external devices, from
19 entering string units 212 and battery cell strings of string units 212. Optoisolator 280 outputs
20 digital signals. Connector 290 is operatively coupled to and receives digital signals from
21 optoisolator 280. In one embodiment, connector 290 comprises long wires so that battery
22 monitor 210 can be remotely situated from other devices such as DCDD 120 of FIG. 1.
23 Connector 290 is operatively coupled and outputs power to optoisolator 280. Connector 290
24 receives power from digital MUX 130 of FIG. 1. Connector 290 outputs digital signals.

25 FIGURE 3 is a block diagram of one embodiment of the present invention. FIG. 3 is a
26 block diagram of one embodiment of string unit 212 of FIG. 2. As shown in FIG. 3, string unit
27 312 includes positive thermal coefficient (PTC) device 320, thermal fuse 330, battery cell string
28 340, fuse 350 and isolation diode 360. PTC device 320 is operatively coupled to thermal fuse
29 330 and reacts to current from battery cell string 340. PTC device 320 provides overcurrent
30 protection with reference to battery cell string 340. In one embodiment, PTC device 320
31 automatically resets when an overcurrent condition ends. In one embodiment, PTC device 320

1 comprises a Raychem© Polyswitch RXE020. Thermal fuse 330 is operatively coupled to and
2 conducts current from PTC device 320. Thermal fuse 330 is operatively coupled and situated in
3 close proximity to battery cell string 340. Thermal fuse 330 is capable of preventing current
4 flow (open switch mode) of battery cell string 340 when increased temperature is detected. In
5 one embodiment, all string units 212 of battery monitor 210 of FIG. 2 include thermal fuses
6 connected in series, where each battery cell string 340 is in close proximity to a thermal fuse.

7 Battery cell string 340 is a string of a battery array. In one embodiment, a battery array
8 comprises 26 battery cell strings, where each string comprises four cells. In one embodiment,
9 battery cell string 340 comprises lithium cells. Fuse 350 is operatively coupled to and receives
10 current from battery cell string 340. Fuse 350 prevents overcurrent conditions. In one
11 embodiment, fuse 350 comprises a standard overcurrent fuse. Fuse 350 outputs current.
12 Isolation diode 360 is operatively coupled to fuse 350. Isolation diode 360 receives current from
13 battery cell string 340 via fuse 350. Isolation diode 360 prevents reverse currents from entering
14 battery cell string 340. In one embodiment, isolation diode 360 comprises a low-loss diode. In
15 one embodiment, isolation diode 360 comprises a Schottky diode. Isolation diode 360 outputs
16 voltage signals.

17 The operation of BSMS 100 is now described with reference to FIGS. 1-3. BSMS 100 of
18 FIG. 1 includes safety devices such as PTC device 320, thermal fuse 330, fuse 350, isolation
19 diode 360 of FIG. 3 and wetness detector 254 and optoisolator 280 of FIG. 2. These safety
20 devices help prevent dangerous conditions, which can lead to damage to and/or explosion of
21 battery cell strings 340 of FIG. 3. Analog MUX 230 of FIG. 2 receives voltage signals from
22 battery cell string 340 of FIG. 3 via isolation diode 360 of FIG. 3. Microcontroller 260 of FIG. 2
23 transmits control signals to analog MUX 230 of FIG. 2, which include input selection
24 information. Analog MUX 230 of FIG. 2 receives voltage signals from a plurality of string units
25 212. Analog MUX 230 of FIG. 2 selects one of a plurality of string units 212 of FIG. 2 to output
26 based on input selection information received from microcontroller 260 of FIG. 2 via control
27 signals. Zener diode 240 of FIG. 2 receives voltage signals from analog MUX 230 of FIG. 2 and
28 reduces the voltage signals to low voltage signals. A/D converter 250 of FIG. 2 receives and
29 converts low voltage signals to digital voltage signals. DCDD 120 of FIG. 1 receives digital
30 voltage signals from battery monitor 210 of FIG. 2. Digital MUX 130 of FIG. 1 receives digital
31 voltage signals from a plurality of battery monitors 110 of FIG. 1. Digital MUX 130 of FIG. 1

1 selects one of a plurality of battery monitors 110 of FIG. 1 to output based on input selection
2 information received from microcontroller 140 of FIG. 1. Microcontroller 140 of FIG. 1
3 displays alerts via display devices 150 of FIG. 1 depending on data (e.g., digital voltage signals)
4 received from digital MUX 130 of FIG. 1.

5 FIGURE 4 is a flowchart of an exemplary method of implementing an embodiment of the
6 present invention. Certain details and features have been left out of flowchart 400 of FIG. 4 that
7 are apparent to a person of ordinary skill in the art. For example, a step may consist of one or
8 more sub-steps or may involve specialized equipment or materials, as known in the art. While
9 STEPS 410 through 460 shown in flowchart 400 are sufficient to describe one embodiment of
10 the present invention, other embodiments of the invention may utilize steps different from those
11 shown in flowchart 400.

12 Referring to FIG. 4, at STEP 410 in flowchart 400, the method measures string voltage
13 periodically. In one embodiment, the method measures string voltage approximately every 10
14 seconds. After STEP 410, the method of flowchart 400 of FIG. 4 proceeds to decision STEP
15 420.

16 At decision STEP 420 in flowchart 400, the method determines whether voltage has
17 dropped a predetermined amount since the last measurement. In one embodiment, the
18 predetermined amount is 25 mV. If the method determines that voltage has dropped a
19 predetermined amount, the method proceeds to STEP 450 whereat the method displays an alert.
20 If the method determines that voltage has not dropped a predetermined amount, the method
21 proceeds to decision STEP 430.

22 At decision STEP 430 in flowchart 400, the method determines whether voltage is below
23 a safe threshold. If the method determines that voltage is below a safe threshold, the method
24 proceeds to STEP 450 whereat the method displays an alert. If the method determines that
25 voltage is not below a safe threshold, the method proceeds to decision STEP 440.

26 At decision STEP 440 in flowchart 400, the method determines whether wetness is
27 detected. If the method determines that wetness is detected, the method proceeds to STEP 450
28 whereat the method displays an alert. If the method determines that wetness is not detected, the
29 method proceeds to STEP 460.

1 At STEP 450, the method displays an alert and proceeds to STEP 460. At STEP 460,
2 the method displays the status of the batteries being monitored. After STEP 460, the method of
3 flowchart 400 of FIG. 4 returns to STEP 410.

4 From the above description of the invention, it is manifest that various techniques can be
5 used for implementing the concepts of the present invention without departing from its scope.
6 Moreover, while the invention has been described with specific reference to certain
7 embodiments, a person of ordinary skill in the art would recognize that changes can be made in
8 form and detail without departing from the spirit and the scope of the invention. The described
9 embodiments are to be considered in all respects as illustrative and not restrictive. It should also
10 be understood that the invention is not limited to the particular embodiments described herein,
11 but is capable of many rearrangements, modifications, and substitutions without departing from
12 the scope of the invention.